U.S DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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PLATE 3 OF 3

DESCRIPTION OF SPECTRAL UNITS

Wet vegetated sandy mud– ~45%–50% water, ~45%–50% dead or senescent (brown, no chlorophyll) and live (green, chlorophyll) grass, and <5% sandy mud exposed at surface

Dry vegetated sand– ~20% live (green) vegetation, 75% dead or senescent (brown no chlorophyll) vegetation, and <5% bare sand. In some areas such as on parabolic dunes, the vegetated sand spectral unit consists of ~20% lichen, ~20% bare sand, ~40% dead vegetation and ~20% green vegetation

Slightly muddy sands– <95% quartz sand, >5% live (green) vegetation, silt, and clay

Clean sands–>95% quartz sand, <5% live (green) vegetation, silt, and clay

Green vegetation– >50% green vegetation cover

Water and Ice–100% water and/or ice

Unclassified

EXPLANATION OF MAP SYMBOLS

Federal Boundary—National Petroleum Reserve, Alaska

Existing Pipeline

Proposed Pipeline Route (approximate, acquired 5/04)

Exploration Well

Proposed Pad (approximate, acquired 5/04)

SCALE 1:63 360

1 MAP INCH = 1 GROUND MILE

Landsat 7 ETM+ data acquired June, 2003
Universal Transverse Mercator projection, zone 5
1983 North American Datum

INTRODUCTION

The northeastern part of the National Petroleum Reserve in Alaska (NPRA) has become an area of active petroleum exploration during the past five years. Recent leasing and exploration drilling in the NPRA requires the Bureau of Land Management (BLM) to manage and monitor a spectrum of surface activities that include seismic surveying, exploration drilling, oil-field development drilling, construction of oil-production facilities, and construction of pipelines and access roads. BLM evaluates a variety of permit applications, environmental impact studies, and other documents that require rapid compilation and analysis of data pertaining to surface and subsurface geology, hydrology, and biology. In addition, BLM must monitor these activities and assess the impacts of these activities to the natural environment. Timely and accurate completion of these land-management tasks requires elevation, hydrologic, geologic, petroleum-activity, and cadastral data, all integrated in digital formats at a higher resolution than currently available in published formats.

To support these land-management tasks, a series of maps have been generated from remotely sensed data in an area of high petroleum-industry activity. The maps, extending from 70°00' to 70°30' N latitude and from 151°00' to 153°10' W longitude, include the Alpine oil field on the east, the Husky Inigok exploration well (site of a landing strip) on the west, many of the exploration wells drilled in NPRA since 2000, and the route of a proposed pipeline to carry oil from discovery wells in NPRA to the Alpine oil field. This map area is referred to as the “Fish Creek area” after the prominent fluvial system within the area.

The map series includes a color shaded-relief map (based on 5 m-resolution data, Plate 1), a surface classification map (based on 30 m-resolution data, Plate 2), and a pan-sharpened, shaded relief-surface classification map (generated by fusing the two datasets, Plate 3). Remote sensing datasets used to compile the maps include, IFSAR, and Landsat 7 ETM+ data. In addition, a 1:250,000 geologic map of the Harrison Bay Quadrangle, Alaska (Carter and Galloway, 1985) has recently been released in digital format (Carter et al., 2005), and was used in conjunction with ETM+ and IFSAR data.

DATA DESCRIPTION

The Landsat 7 ETM+ radiance-at-the-sensor data were acquired on June 6, 2003, and consist of six bands at 30 m resolution in the 0.4 to 2.5 µm region, one band at 90 m resolution centered at 11.45 µm, and one 15 m resolution panchromatic band. The thermal infrared and panchromatic bands were not used in this study. The Landsat 7 ETM+ scene was calibrated to reflectance using an ENVI (Environment for Visualizing Images) reflectance algorithm (RSI, 2000). Evaluation of the reflectance data indicated that values in bands 1-4 were anomalously high, and thus, a dark object subtraction method (Crain, 1971) was used to correct for the optical scattering of light in bands 1-4. A subset of the reflectance Landsat 7 ETM+ scene was then extracted to cover the NPRA study area.

Spectral analysis of target training areas was used to define spectral map units referred to in this report as “spectral units”. Landsat 7 ETM+ data were used to identify specific materials or mixtures of materials on the basis of their spectral characteristics and ground truth data obtained from the study area in July 2004. Library spectra (resampled to Landsat 7 ETM+ bandpasses), of typical materials found at NPRA such as green vegetation, quartz sand, dead vegetation, and clay (montmorillonite), have distinct spectral signatures that can be mapped using spectral shape-fitting algorithms. Image spectra used to define spectral units contain mixtures of green vegetation, quartz sand, dead vegetation, and clay and thus have spectral signatures that consist of multiple spectral features.

The thaw lakes still contained a substantial amount of ice as well as water when the image was acquired in June 2003. Reflectance image spectra of ice, water, vegetation and soil illustrate that ETM+ band 5 (1.65 micrometers) digital number (DN) values are lower for ice and water, than band 5 DN values for vegetation and sediment spectra. Thus, on the basis of water, ice, and vegetated sediment spectra, a threshold of ETM+ band 5 was used to map the thaw lakes and other water and ice bodies.

An image spectrum from the study area and a resampled spectrum of green vegetation from a spectral library both indicate a chlorophyll absorption feature at 0.66 micrometers. A Landsat 7 ETM+ band ratio of 4/3 produces an image with high DN values where there are relatively strong chlorophyll absorption features, and thus, the green vegetation spectral unit was mapped by applying a threshold to an ETM+ band ratio 4/3 image. Field observations indicate that areas that contained more than 50 percent green vegetation classified as the green vegetation spectral unit.

In order to map additional surficial units, a false color composite (R=7, G=4, B=2) ETM+ image was assessed to select image spectra. Due to high spectral contrast, a water/ice mask was applied to the false color composite (R=7, G=4, B=2) ETM+ image to improve spectral variability. Spectral units other than green vegetation and water were defined by examining the spectral characteristics of image spectra associated with specific geomorphic features such as dunes, river bars, and lake shorelines. Selection of specific landforms was based on inferred sediment types associated with the depositional environment that produced the landform, and from the USGS 1:250,000 -scale engineering geologic map of the study area (Boggs, 1995; Carter and Galloway, 1985). Approximately 20 image spectra were selected from the false color composite ice and water masked image. Interpreted spectral units using this process include, vegetated dry sand from linear ridges, clean sand from active dunes around thaw lakes, muddy sand from sand bars in rivers, and wet vegetated sandy mud from lake sediments in thaw lakes.

Matched filtering, an algorithm for detecting target spectra in the presence of spectral mixtures (Harsanyi and Chang, 1994; Farrand and Harsanyi, 1997), was used with the image spectra to produce a series of gray scale images. The images were qualitatively assessed for spatial coherence and accuracy. Four images were selected and interpreted to represent mixtures of sediment, water, and vegetation on the basis of their spectral properties, similar distribution in relation to lithologic units of the geologic map (Carter and Galloway, 1985), a 5 m digital terrain model of the IFSAR data, and the water-masked false color composite RGB Landsat 7 ETM+ image (Plate 1). A threshold was applied to each grayscale image to remove noise, poor matches and similar mapped pixels. Each processed image was then combined to produce a provisional classification map.

The provisional surficial classification map was assessed in the field for consistency and accuracy of the spectral units with respect to surficial material assignments such as sediment, water and vegetation content. An Analytical Spectral Devices (ASD) field spectrometer was used to collect reflectance spectra in the field and was used to collect reflectance spectra from field samples in the laboratory. The ASD field spectrometer collects reflectance data at 1 nanometer spacing from 0.35 µm to 2.5 µm. Comparison of field and lab spectra from selected calibration sites consisting primarily of windblown quartz sands indicated that no additional calibration of the ETM+ dataset was necessary. In addition, field and lab spectra were also compared to image spectra for evaluation of material content and accuracy of spectral units.

IFSAR data used in the study were collected by the STAR-3i airborne synthetic aperture radar system. STAR-3i is a high-resolution, single-pass, across-track IFSAR system, which uses two apertures to image the surface. The path length difference between the apertures for each image point, along with the known aperture distance, is used to determine the topographic height of the terrain. The IFSAR system is capable of collecting data with a vertical accuracy of <1 m and a horizontal accuracy of <3 m.

Data are delivered as three core products: orthorectified radar images (ORRIs), digital surface models (DSMs), and digital terrain models (DTMs). ORRIs are 8-bit grayscale GeoTIFF images that show the radar reflectance intensity of various earth surface materials. These images are commonly used to identify and extract drainage networks and cultural features such as pipelines, roads, and buildings. The ORRIs used in this study had a pixel size of 1.25 m and a horizontal accuracy of 2.5 m. The DSMs, or “first-return” elevation data, display the first surface on the ground that the radar strikes. These images consist of measured points collected by the sensor, including the z-values of structures (e.g., building and towers) and vegetation (e.g., trees and crops). These elements are removed from the DSM through filtering techniques to create a DTM. The DTMs, or “bald-earth” elevation data, are similar to Digital Elevation Models (DEMs) in that non-terrain elements are absent. However, unlike the regular array of elevation values that are characteristic of a DEM, a DTM defines topographic elements by irregularly spaced breaklines, or abrupt changes in surface smoothness, like shorelines, roads, streams, and slope breaks. The result is a more accurate depiction of the terrain, useful for contouring, triangulated irregular network (TIN) calculations, and other terrain modeling.

In fusing datasets, the 30 m surficial classification map was resized to match the dimensions of the 5 m DTM hillshade image in ERDAS Imagine. A median filter was applied to alleviate pixelization native to the 30 m dataset when viewed at full resolution. Datasets were fused using raster arithmetic operators in ArcGrid and then downsampled appropriately based on desired hardcopy map scale.

DATA INTERPRETATION

The shaded relief-surface classification map combines the 5 m IFSAR data and the ETM+ surficial classification map. The color classification scheme is the same as the surface classification map, however, light-gray to black hillshading from the DTM has been added to enhance surface features.

Specific spectral units or combinations of spectral units tend to correlate with specific topographic features such as eolian and coastal ridges and river valleys. A combination of shaded relief, and dry vegetated sand, sandy mud, and unclassified pixels define east to northeast trending ridges capped by parabolic dunes in the western part of the study area (Plate 3). Pixels classified as dry vegetated sand primarily cover the ridges and dunes and unclassified and wet sandy mud pixels dominate the inter-dune and inter-ridge areas (Plate 3).

Low-profile (> 10m) river valleys dominate the eastern part of the study area (Plate 3). Meandering channels are slightly incised and the sediments in active channels are classified primarily as clean and slightly muddy sands. Adjacent to the active fluvial channels are low-profile water and sediment-filled abandoned channels and thaw lakes, which classify as water, and wet vegetated sandy mud (Plate 3). Bordering the active and abandoned channels are low-relief terraces classified as dry vegetated sand (Plate 3). Field investigations indicate that some of the low-relief terraces are capped by eolian reworked fluvial deposits. Flanking the low-relief terraces are broad flat interfluvial plains that are classified as wet sandy mud, dry vegetated sand, green vegetation and unclassified pixels (Plate 3). The broad plain areas contain an abundance of sandy mud and water-filled thaw lakes. Some of the lakes and lake deposits tend to form groups of northeast trending topographically low areas and may indicate locations of older abandoned stream and river channels.

The shaded relief-surface classification map illustrates a close relationship between surficial vegetation and topography, which may be linked to the availability of water for vegetation and depth to permafrost. The DTM shows that the eolian and coastal ridges, which cover the western part of the study area, are up to 500 m wide, average 4 km in length, and have vertical profiles of approximately 18 m (Plates 1, and 3). Up to 60 percent of the vegetation on these dunes was either senescent or dead (brown to light gray in color). Vegetation types on eolian and coastal ridges included sedges, lichens, and mosses. Field investigations show that the floodplain and river valley areas in the eastern part of the study area contain up to 80 percent green vegetation, consisting of sedges, dwarf willows and alders, perennials, and mosses. Thus, field observations suggest that there is significantly more moist vegetation and standing water in the river valleys than the eolian and coastal ridges. Shallow pits dug in the field indicate that depth to permafrost was 0.5 m - 1.2 m in the eolian and coastal dune areas and 0.2 m - 0.4 m in the eastern fluvial dominated topography. The differences in depth to permafrost may be due to either better drainage of the eolian and coastal dune sediments or greater exposed surface area of the dunes, which would increase the rate of melting permafrost. Due to the extremely dry conditions of < 10 cm of precipitation per year (NOAA, 2005), water perched above the permafrost is a major source of water for vegetation. Thus, increased depth to permafrost would create more arid surface conditions favoring stressed vegetation and organisms such as lichens that thrive in relatively arid conditions.

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SHADED RELIEF–SURFACE CLASSIFICATION MAP OF THE FISH CREEK AREA, HARRISON BAY QUADRANGLE, NORTHERN ALASKA